Measurement of the gravitational constant G by atom interferometry

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We will report on the accurate measurement of the gravitational constant G with an atomic sensor. The experiment is based on a light-pulse atom interferometry gravity gradiometer detecting the gravitational field generated by a well characterized set of source masses (fig. 1).

^{87}Rb atoms, trapped and cooled in a magneto-optical trap (MOT), are launched in a vertical vacuum tube, producing an atomic fountain. Near the apogees of the atomic trajectories, a measurement of their vertical acceleration is performed by a Raman interferometry scheme. External source masses are positioned in two different configurations (C_1 and C_2) and the induced phase shift is measured as a function of masses positions.

After a preliminary measurement with $\sim 0.1\%$ precision [1], we recently operated several upgrades to improve the sensitivity and the control on sources of systematic errors [2]. We achieve a short term sensitivity of $3 \times 10^{-9}\,\mathrm{g}/\sqrt{\mathrm{Hz}}$ to differential gravity acceleration, limited by the quantum projection noise of the instrument. Active control of the most critical parameters allows to reach a resolution of $5 \times 10^{-11}\,\mathrm{g}$ after 8000 s on the measurement of differential gravity acceleration. Fig. 1 shows the data used for the determination of G. The modulation of the differential phase shift produced by the source mass is well visible and can be resolved with a signal-to-noise ratio of 1000 after about one hour. The resulting value of the differential phase shift is 0.547870(63) rad from which, after evaluation of systematic shifts and errors, we obtained the value of $G = 6.67191(99) \times 10^{-11}\mathrm{m}^3\mathrm{kg}^{-1}\mathrm{s}^{-2}$.

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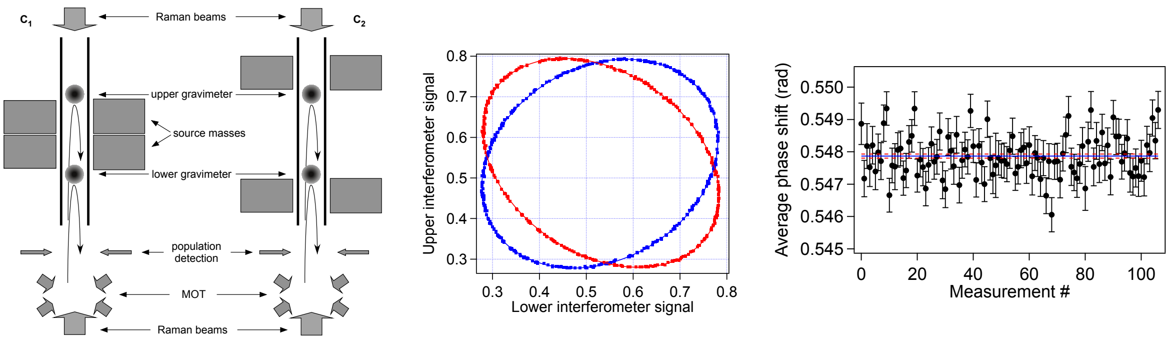

Figure 1: *Left: scheme of the MAGIA experiment. Center: typical Lissajous figures obtained by plotting the output signal of the upper atom interferometer vs the lower one for the two configurations of the source masses: C_1 (red) and C_2 (blue). Left: Results of the measurements to determine G. Each point is the difference of the phase angle recorded for the two configurations of the source masses. The data acquisition for each point took about one hour. These data were recorded in different days spanning over one week in July 2013. The error bars are given by the combined error on the ellipse angles.*

References

[1] G. Lamporesi et al., *Determination of the Newtonian Gravitational Constant Using Atom Interferometry*, Phys. Rev. Lett. **100** 050801 (2008).
[2] F. Sorrentino et al., *Sensitivity limits of a Raman atom interferometer as a gravity gradiometer*, Phys. Rev. A **89** 023607 (2014).